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High Power, High Efficiency MESFETs and HEMTs

Project # : AFOSR-F49620-92-J-0366
Dates : 6/15/92 - 6/14/95

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ABSTRACT:

For the duration of the project dated above, the work on the AASERT program concentrated on improving the power performance of GaAs MESFETs with LTG GaAs surface passivation layers by studying the effects of source and drain contacts regrown by MOCVD on both device breakdown and gain.

Breakdown Behavior:

The breakdown in GaAs based FETs occurs at either or both of the regions where electric field peaks in the device, the drain edge of the gate and the gate edge of the drain. The gate breakdown is currently being addressed by utilizing LTG GaAs passivation to alleviate the surface field (under AFOSR-F49620-94-1-0040). The drain field, however, increases in this arrangement because of exarcebated current crowding at the drain because of the lack of an effective gate recess. Figure 1 schematically compares the current flow in LTG GaAs FETs and conventional FETs. The increase in the field leads to instabilities in the drain charcteristics at high current levels and premature breakdown. To address this issue we have investigated regrown ohmic contacts by MOCVD.

Device Characteristics with Regrown Contacts:

The typical device structure studied is shown in figure 2. The source and drain regions were grown selectively by MOCVD using SiO_2 as a mask. The non-alloyed ohmic contact resistance in devices with the regrown contacts is similar to the best alloyed contacts (0.1ohm-mm). The advantages of the regrown contact are that:

(i) the non-alloyed contact is extremely **stable,**
(ii) there is **no spiking** of the contacts and hence no regions of high field concentration, and
(iii) there is **no hole injection** from n+ regions as opposed to alloyed metals.

The third advantage bears explanation as it has great impact on the reliability of the FET. As shown in Figure 3 the high electric field near the metal coupled with a narrowed band gap adjacent to the alloyed metal causes

injection of valence band electrons into the metal, or equivalently hole injection from the metal. The injected hole current drifts towards the source and the gate electrode. The lateral current density(A/mm) gets converted into a very high areal current density (A/cm2) as it flows into the gate leading to failure. In the case of the regrown contacts

(i) the hole density is extremely small in the n+ regions, and
(ii) the field is effectively quenched before reaching the drain metal.

Both have the effect of substantially relieving instabilities and improving device reliability.

Results:

Figure 4 shows the I-V characteristic of devices with and without regrown contacts. The devices with regrown contacts have extremely stable I-V characteristics and can sustain much larger voltages at full channel current. Since this is the bias condition that maximizes drain field, it is clear that regrown contacts have relieved the field effectively. The active device parameters such as g_m and I_{dss} are similar for devices using either contact technology. We therefore believe that though further study is needed to quantify each current component, regrown ohmic contacts will find increasing use in high reliability power applications.

Figure Captions:

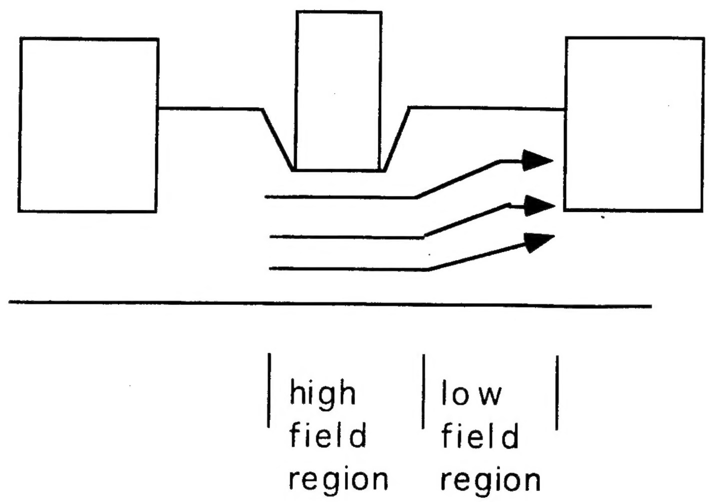
Figure 1 : a) Currents flow in a conventional MESFET. b) Currents flow in a MESFET with LTG-GaAs passivation.

Figure 2: Schematic cross-section of a device with MOCVD selective regrown source/drain contacts.

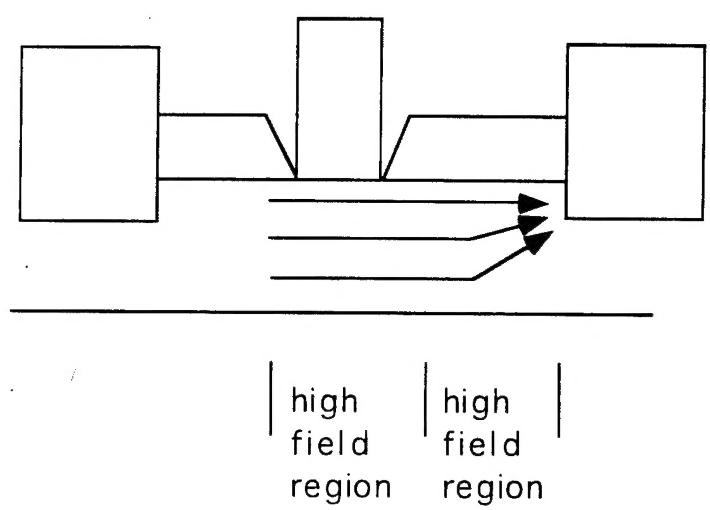
Figure 3: Holes injection from the metal into the channel at the drain contacts.

Figure 4: a) Current-voltage characteristics of a device with conventional contacts. b) Current-voltage characteristics of a device with regrown source/drain contacts.

a)


high
field
region
low
field
region

b)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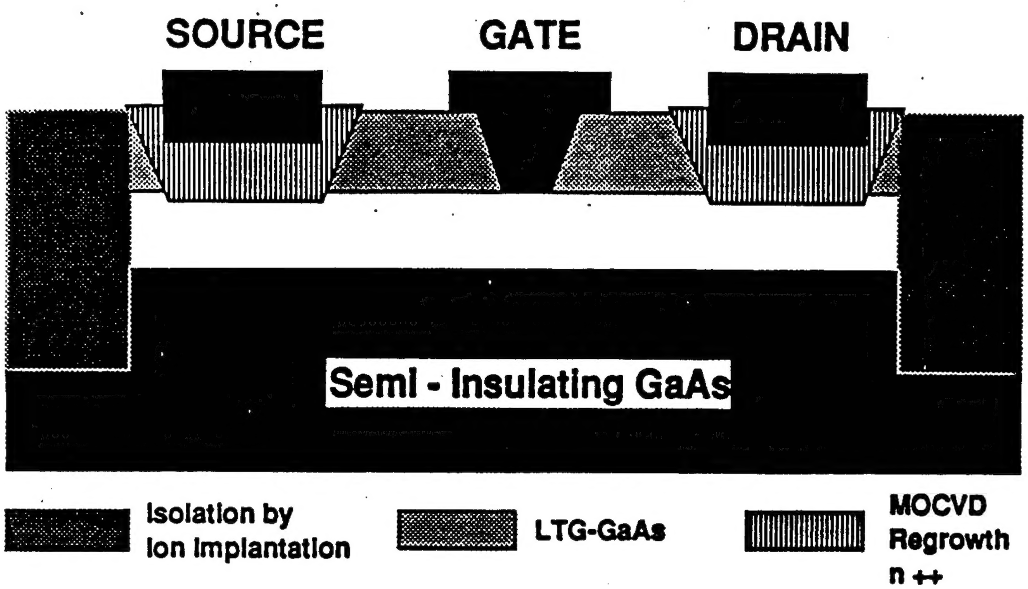
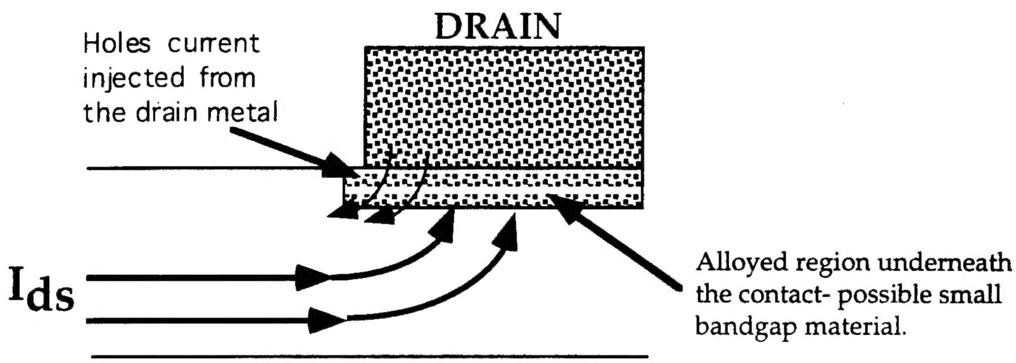
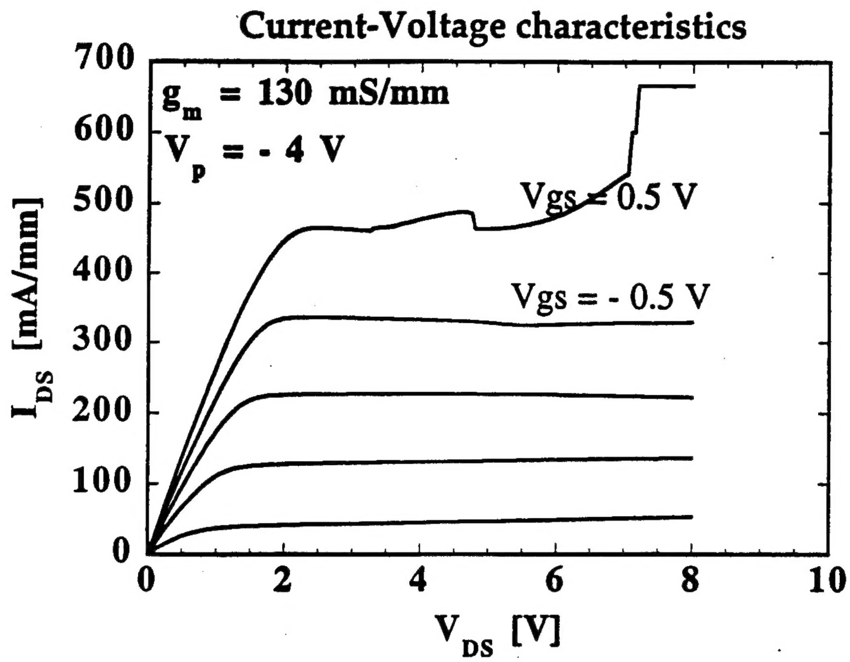
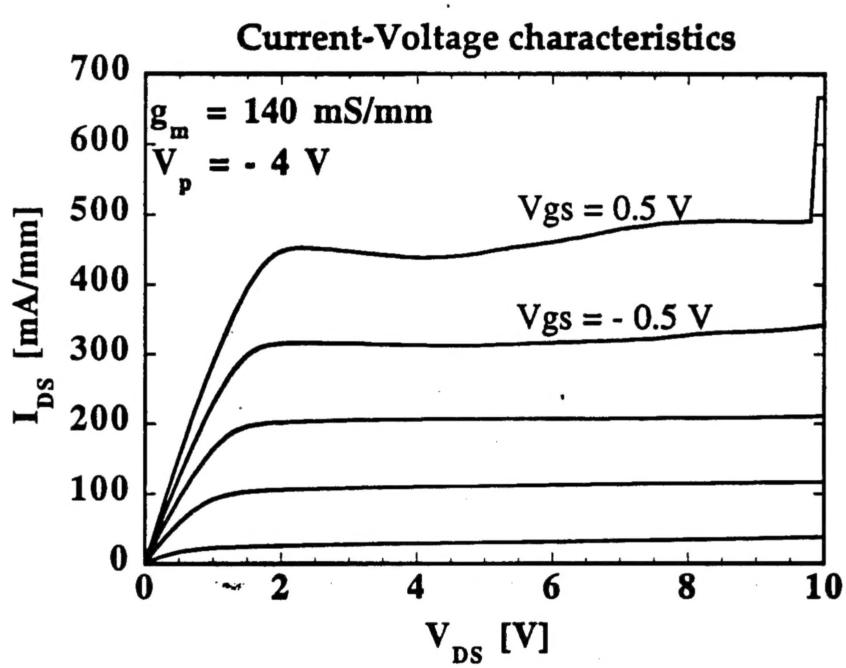

SOURCE
GATE
DRAIN
Semi - Insulating GaAs
Isolation by
Ion Implantation
LTG-GaAs
MOCVD
Regrowth
n ++


DRAIN
Holes current
injected from
the drain metal
Alloyed region underneath
the contact- possible small
bandgap material.
I_{ds}


Current-Voltage characteristics
g_m = 130 mS/mm
V_p = - 4 V
Vgs = 0.5 V
Vgs = - 0.5 V
700
600
500
400
300
200
100
0
I_{DS} [mA/mm]
0
2
4
6
8
10
V_{DS} [V]


Current-Voltage characteristics
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V_p = - 4 V
Vgs = 0.5 V
Vgs = - 0.5 V
700
600
500
400
300
200
100
0
I_{DS} [mA/mm]
0
2
4
6
8
10
V_{DS} [V]